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Assessing the Effect of Aflatoxin on Maize Production in Southwest Nigeria

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Abstract: The risks of mycotoxin exposure have been widely accepted. The key object of the manuscript is to examine the effect of aflatoxin on maize production in the study area. This was achieved by comparing the profitability and output of maize farmers not affected by aflatoxin and those affected in southwest, Nigeria. Multistage sampling procedure was used to sample 400 respondents (200 maize farmers not affected by aflatoxin, and 200 maize farmers affected by aflatoxin). The result revealed that the net profit margin ratio for the not affected maize farmers was 36.33%, and affected maize farmers was 26.66%. The study revealed that age, household size, fertilizer application, and awareness regarding combating aflatoxin had negative but significant relationship with combating aflatoxin using agrochemicals in the study area. The output of maize farmers affected by aflatoxin was 15.94% lower compared to the not affected maize farmers. The study suggests that maize farmers ought to be sensitized and encouraged by policymakers and non-government organizations on the need to combat aflatoxin to increase output from their maize production.

Keywords: Maize farmers, Aflatoxin, Output, Endogenous Switching Regression Model, Southwest Nigeria

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1. Introduction

Maize account for one of the most crucial dietaries in the world, its consumption is second to wheat and rice and with refence to its cultivation and production (Hossain, 2020). Maize has the ability and capability to thrive in all the world agroecological zones, hence, it is planted in all the regions of the world in the seven continents. With refence to the International Institute for Tropical Agriculture (IITA), globally, maize production is around 785 million tons, and it is being consume by over 1.2 billion people all over the world and 300 million of the 1.2 billion are from Sub Sahara Africa (SSA) in 2013 (Ranum et al., 2014).

United States of America (USA) is top maize producer contributing 42% of global maize production. While African account for 6.5%, Nigeria is the largest producer in Africa, producing 8 million tons (Price Waterhouse Corporation (PWC), 2021). However, there are various diseases associated with maize, some are from pests or viruses like aflatoxin that are naturally occurring in the soil.

Aflatoxins are toxic ingredients produced by certain types of fungi (molds) that are common all over the world; the Aflatoxins producing fungi, *Aspergillus* ssp., are naturally occurring, contaminating foods supplies and poses a serious risk to both humans and livestock (World Health Organization (WHO, 2018). They are the main causes of disease epidemic due to lack of awareness and eating of contaminated food like maize, millet and which often result in reduction in agricultural production (Kumar et al., 2016). The effect of aflatoxin in Africa is mostly felt in the contamination of mostly consume foods such as maize,

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groundnuts and rice. Especially affecting near crop maturity under dry weather conditions. Due to climatic conditions, crop produced in the most of African countries are susceptible to aflatoxin contamination (Achaglinkame, 2017).

In the pre- and post-harvest stages, aflatoxin can be curtailed, therefore, farmers can potentially control aflatoxin before harvest as well as after harvest. The most potent pre-harvest strategy to curtail aflatoxin contamination is by improving crop resistance against fungal infection or avert production of aflatoxins by attacking fungus using appropriate agrochemicals (Atuhe, 2021). The most commonly and efficient pre-harvest method of curtailing aflatoxin in most African countries has been biological control using non-toxigenic *A. flavus* isolates (WHO, 2018). The method has been used on maize in different countries, (Agbetiameh et al., 2020; Jallow et al., 2021; Ponce-Garcia et al., 2021; Moral et al., 2020; Savić et al., 2020). Adequate storage condition system such as elimination of insect that damages maize, aeration, adequate temperature and moisture can be helpful in preventing contamination and toxin production by mold (Annunziata et al., 2021; Imade et al., 2020; Villers, 2014; Xu et al., 2022).

The economic losses associated with aflatoxins are estimated to be large (Mitchell et al., 2016), these losses are expected to rise due to changing climatic conditions (Leggieri et al., 2021; Nishimwe et al., 2019; Yu et al., 2020). Over 750 million USD were estimated to be lost in Africa due to aflatoxin contamination of agricultural outputs. Likewise, European Union (EU) spent over 670 million USD to control aflatoxin yearly (Udomkun et al., 2017). For example, in Nigeria, about 30% of the harvested maize has high levels of aflatoxins and are likely to be rejected in both national and international markets (IITA, 2019). So, the study examined the effect of aflatoxin on maize production profitability and maize farmers output in the Southwest Nigeria. Net Profit Margin Ratio (NPMR) and Endogenous Switching Regression (ESR) model were used to analysis the data collected. It is expected that the result of the study will guide policy makers on how best to implement various agricultural interventions in Nigeria, Sub-Sahara Africa (SSA) and other tropical and sub-tropical countries with respect to the need to combat aflatoxins among the maize farmers and other arable crops.

2. Materials and Methods

2.1. Study Area, Source of Data, Sample Techniques and Size

The study was conducted in in Ondo and Oyo States, southwest Nigeria. The two states consist of 51 Local Government Areas (LGAs) (i.e., Ondo State has 18 LGAs and Ekiti State has 33). The population of the two states is 9041771 (i.e., Oyo is 5,580,894 and Ondo is 3,460,877) (National Bureau of Statistics (NBS, 2018). Data for the study were from main sources. Main data were collected using well-structured questionnaire for the period of 2018/2019 farming season. Information that was collected includes the socio-economics characteristics, cost of production, output, prices and income from maize production. The population for the study included maize farmers affected by aflatoxin and maize farmers not affected by aflatoxin.

Multistage sampling procedure was used to choose the respondents. Firstly, there was a deliberate selection of two states (Ondo and Oyo State) because the two states are known for maize production in the Southwest, Nigeria (NBS, 2018). Secondly, two Local Government Areas (LGAs) that are recognized for maize production in each state were selected for the study. Thirdly, there was random selection of five (5) communities in each of the LGAs through the assistance of Agricultural Development Programme (ADP) extension agents. In each community, ten (10) maize farmers who were affected by aflatoxin (Farmers who did not use agrochemicals to combat the effect of aflatoxin) and ten (10) maize farmers who were not affected by aflatoxin were selected (Farmers who used agrochemicals to combat the effect of aflatoxin). Therefore, two hundred (200) maize farmers who were affected by aflatoxin and two hundred (200) maize farmers who were not affected by aflatoxin were the respondents for the study.

2.2. Data Analyses

2.2.1. Profitability Measurement

Net Income (NI) and Net Profit Margin Ratio (NPMR) assessment was carried out to measure the profitability of maize production among the maize farmers affected by aflatoxin and those not affected by aflatoxin in the study area.

$$NI = TR - TC \quad [1]$$

$$NPMR = (\text{Net Income} \div \text{Revenue}) \times 100 \quad [2]$$

In determining the effect of aflatoxin on maize profitability of both the not affected and the affected in the study area, NPMR was used, because the method allows two businesses of different sizes to be compared at a period (Tulsian, 2014). Therefore, it gives a realistic performance of such businesses and one can know which one is performing better among the businesses.

2.2.2. Model for the Effect of Aflatoxin on Maize Production

The assumption is that maize farmers are risk neutral and appraise benefits associated with not affected by aflatoxin. Affected and not affected by aflatoxin is represented by β_{iA} and β_{iN}, respectively. Also, it is assumed that household net benefits and other preferences are only known to the maize farmers, while not affected by aflatoxin status is known to the person carrying out the research. Therefore, unobserved net benefits of maize farmer *i* is expressed as $\beta_i^* = \beta_{iN} - \beta_{iA}$. The elementary association applied here is that net benefit from not affected by aflatoxin is related to a vector of household explanatory variables *(X_i)* in a latent framework which is described in equation 3.

$$\beta_i^* = X_i'\gamma + \mu_i = 1[\beta_i^* > 0], \quad [3]$$

Where β_i represents a dummy variable with 1= not affected by aflatoxin and 0 = affected by aflatoxin, *X* stands for all observable factors that affect the use of agrochemicals to combat the effect of aflatoxin, γ stands for a vector of parameters to be estimated, µ stands for the error term with mean zero and variance σ_μ^2 that captures measurement errors, and unobserved issues.

The association that is being considered in assessing the effect of aflatoxin on maize farmer's output assumes that the vector of outcome variable is a linear function of a vector of explanatory variables *(P_i)* and not affected status that is a dummy variable (β_i). The association is expressed as follows:

$$R_i = P_i'v + \beta_i \acute{\alpha} + \varepsilon_i \quad [4]$$

Where variable R_i is a vector of outcome variable, P_i is a vector of farm and household characteristics, β_i stands for not affected by aflatoxin, ε_i stands for random error term, while v and ά are vector of parameters to be estimated.

Following Thompson et al. (2021) and Endogenous Switching Regression (ESR) model approach, developed by Lokshin and Sajaia, (2004), was used to simultaneously estimate the determinants and effect of aflatoxin on output of maize farmers, which also accounts for observable and unobservable factors in a well-organized manner. Endogenous Switching Regress\ion (ESR) is very suitable for this study since the outcome variable, output, is continuous in nature.

A two-stage estimation technique was simultaneously estimated while modelling the effect of aflatoxin on maize farmers' output using the ESR framework.

The first stage involved the estimation of variables inducing the use of agrochemicals to combat aflatoxin as shown in equation (3). In the second stage, the connection between the outcome variable and the explanatory variables specified for two regimes of not affected and affected was estimated. The specifications for the two regimes are given as follows.

Regime 1 (Not affected by Aflatoxin):

$$R_{iN} = \rho' V_{iN} + \varepsilon_{iN} \text{ if } \beta_i = 1 \quad [5a]$$

Regime 2 (Aflatoxin-Affected):

$$R_{iA} = \rho' V_{iA} + \varepsilon_{iA} \text{ if } \beta_i = 0 \quad [5b]$$

Where R_{iN} and R_{iA} are outcome variable for not affected by aflatoxin and affected by aflatoxin, respectively; P_i' is a vector of farm and household characteristics; ε_i stands for random error term, while v is a vector of parameters to be estimated. It is vital to use one or more variables which do not come up in P for identification purposes. This is done such that selection and outcome equations are estimated using the same set of variables, but with additional variable being used as an instrument in the selection equation.

The strategy used in this study is awareness about the importance of combating aflatoxin using agrochemicals. Being aware about the importance of combating aflatoxin using agrochemicals can influence not affected status, and not the outcome. Selection bias problem due to unobservable variables within the structure of omitted variable problem can be easily addressed. According to Heckman, (1979), there is an inclusion of selectivity terms used in the selection equation represented by θ_N and θ_A for not affected and affected, respectively as well as covariance terms Φ_{NA} and $\Phi_{N\varepsilon}$ in equation 5a and 5b which brought about equation 6a and 6b;

$$R_{iN} = \rho' V_{iN} + \Phi_{NA}\lambda_N + \emptyset_{iN} \text{ if } \beta_i = 1 \quad [6a]$$

$$R_{iA} = \rho' V_{iA} + \Phi_{N\varepsilon}\lambda_A + \emptyset_{iA} \text{ if } \beta_i = 0 \quad [6b]$$

Where the selectivity terms λ_N and λ_A correct for selection bias from unobservable factors and $\emptyset_{iN}$ and $\emptyset_{iA}$ are the error terms with conditional zero means. The approach used in this study is the maximum likelihood approach as proposed by Lokshin and Sajaia, (2004), and used by Thompson et al. (2021).

The ESR model is used to evaluate the effect of aflatoxin on maize farmer's expected output by comparing the expected output of maize farmers who combat aflatoxin using agrochemicals with the outcome expected values of the outcome P on not affected and affected are expressed as follows:

$$E(R_{iN}|\beta = 1) = \rho' V_{iN} - \Phi_N \lambda_N \quad [7a]$$
$$E(R_{iA}|\beta = 1) = \rho' V_{iA} - \Phi_A \lambda_A \quad [7b]$$

Following Lokshin and Sajaia, (2004), the Average Treatment Effect on the treated (ATE) is a change in the expected outcome due to not affected, which is expressed in equation 7 as the difference in the expected outcomes from equations 6a and 6b.

$$ATT = E(R_{iN}|\beta = 1) - E(R_{iA}|\beta = 1) \quad [8a]$$
$$ATT = \rho(V_{iN} - V_{iA}) + \Phi(\lambda_N - \lambda_A) \quad [8b]$$

Where λ stands for covariance of the error terms and Φ the inverse mills ratios or selectivity term.
The following variables were used in the model.

ρ_1 = Gender (1 if male, 0 otherwise)
ρ_2 = Age (in years)
ρ_3 = Age^2 (in years)
ρ_4= Marital status (1 if married, 0 otherwise)
ρ_5 = Years of education (in years)
ρ_6=Household's size (in numbers)
ρ_7= Farming experience (in years)
ρ_8= Access to credit facilities (1 if have access 0 if otherwise)
ρ_9= Membership of Association/Cooperative (1 if a member 0 if otherwise)
ρ_{10} = Family labor
ρ_{11} =Hired labor (man days)
ρ_{12}= Maize seedlings (in Kilograms)
ρ_{13}= Quantity of fertilizer (Kilograms)
ρ_{14}= Quantity of herbicide (Liters)
ρ_{15} = Farm size (hectare)
ρ_{16} = Awareness of importance of combating aflatoxin (1 if aware and 0 if not).

3. Results and Discussion

3.1. Socioeconomic Characteristics

Table 1 presents the result of maize farmers' demography who remained unaffected by aflatoxin and those affected by aflatoxin. In ascertaining the significance of the differences between the demography result of the not affected and the affected, t-test statistics were used with respect to some household and farm-level characteristics. The mean age of maize farmers who are not affected by aflatoxin was 43.7 years and of those affected was 58. 3 years. This implies that most of the respondents were still at their productive age. However, the affected maize farmers were much older relative to the not affected maize farmers. So, the not affected maize farmers should be more productive than the affected (Yazd et al., 2019).

Level of education of not affected maize farmers (92.5%) was significantly different from the affected maize farmers (65.2%). Therefore, most of the farmers who are not affected by aflatoxin by using agrochemicals can read and write. Hence, they understand the advantage of using agrochemicals to combat the effect of aflatoxin in maize production. This buttresses the findings of (Dimick, 2012). that education enhances farmers' productivity by enhancing his/her ability to appropriate knowledge and information in the usage of the right inputs to maximize his/her agricultural output in the competitive agroeconomic structure. This reflects in their ability to make informed decisions in the adoption of new technologies and innovation.

The family size of the not affected was four (4) and that of the affected was eight (8). Family size (Household size) is very crucial to farmers in developing countries especially in Sub-Sahara Africa (SSA), because of common usage of family labor. The family size will determine the extent to which family labor will be used to augment farm work as the case in Mexico (Posadas-Dominguez et al., 2014). So, there is a probability of the affected farmers using family labor compared to the not affected farmers that will likely hire labor.

The ratio of unaffected maize farmers was 88.6%, where all farmers were married, and all the affected maize farmers were also married. Like the family size, marital status was significant because there is the likelihood of the married maize farmers' family being involved in farm work, hence, this will reduce the cost of labor according to the respondents. So, the marital status of maize farmers had a lot of impact on their production efficiency. The spouses often assist in the selling of the maize to the final consumers as seen in Ethiopia (AgroBig Team, 2016).

As shown in Table 1, 12.6 years was the mean farming experience for the not affected farmers and 27.8 years for the affected farmers. The result lay credence to the fact that maize farming is not a novel agribusiness in the study area. Hence, the knowledge acquired through experience over time will be an added advantage in the production process on the farm (Thompson, 2013). The affected had more experience than the not affected probably because they were older. 4.8 hectares was recorded as the mean farm size of the not affected farmers and 2.5 hectares for the affected. The difference in the farm size could be because of the higher educational background of the not affected.

Table 1. Respondents Distribution by Socioeconomic Characteristics

Variable	Not Affected		Affected		Difference
	Mean	Main Indicator	Mean	Main indicator	
Age	43.7 years	98.0% falls below or equals 40 years (active)	58. 3 years	43.0% falls below or equals 40 years (active)	-14.6 years**
Education Level		92.5% had secondary school education		65.2% had secondary school education	27.3%***
Household Size (Number)	4 persons	98.0% between 1and 5 persons as family member	8 persons	51.8% between 1 and 5 persons *as* family member	-4 persons***
Marital Status		88.6% married		100% married	-11.4%**
Farming Experience (Years)	12.6 years	72.8% between 1 and 10 years	27.8 years	12.0% between 1 and 10 years	-15.2 years*
Farm Size (Meter square)	4.8ha	95.0% equal to or above two hectares	2.5ha	35.0% on equal to or above two hectares	2.3ha**
Membership of Cooperative/Association		90.0% registered member of an association or cooperative society		56.0% registered member of an association or cooperative society	34%***

*10%, **5%, and ***1% significance levels

There was a positive correlation between the farm size cultivated by a farmer in developing countries and the level of education, the more educated a farmer is, the bigger the farm size as revealed among the farmers in Vietnam (Ninh, 2021). The majority (90.0%) of the un-affected farmers and half (56.0%) of the affected were members of an association and cooperative society. Membership in an association or cooperative society enhances farmers' productivity (Thompson and Amos, 2017). The variable was significant because when farmers belong to an association or cooperative, it enables them to have access to credit facilities and they can buy input in bulk and at cheaper rates.

3.2. Estimation of Effect of Aflatoxin on Profitability of Maize Production in the Study Area

Not affected by aflatoxin maize farmers and affected maize farmers average costs and return per annum is presented in Table 2. As shown in the Table, the t-test values show the statistical differences in the costs and return of the not affected by aflatoxin maize farmers and those affected by aflatoxin. The shows that the Total Revenue (TR) for the not affected was N3,744,000 ($8,914.29) and N1,950,000 ($4,642.86) for the affected. The quantity of maize in 50kg bags sold by the not affected maize farmers was 288 bags and for the affected was 150 bags per annum. The price of 50kg bags of maize in the study area was N13,000 ($30.95) in the market. The fixed cost (Cost of depreciation of farm equipment) accounted for the highest percentage of the Total Cost (TC) among the not affected (28.95%) and affected (40.23%). The fixed cost share of the TC was higher among the affected compared to the not affected, showing that the optimization of the farm equipment among the affected was lower compared to the not affected maize farmers. Hence, the not affected maize farmers were making better use of their farm equipment compared to the affected maize farmers (Colnago and Dogliotti, 2020). The average cost of land preparation was the second most important variable cost in maize production in the study area accounting for 18.27% and 15.86% for the Total Cost (TC) respectively for the not affected and the affected. The States selected for the study falls within the rainforest zone of the Country, hence, the most crucial cost in the is cost of land preparation for farming (Oluyede et al., 2021).

The cost of weeding was statistically difference between the not affected and the affected. The costs of weeding for the not affected farmers was N102,314.25 ($243.61) and N53,288.68 ($126.88) for the affected. This buttresses the assertion of (United State Department of Agriculture (USDA), 2022) that the bigger the farm size, the more the labor that will be needed for weeding, hence, the higher the cost of weeding. N1,693,819.65 ($4,032.90) and N854,754.39 ($2,035.13) were recorded as the Total Cost Variables (TVCs) of the not affected maize farmers and affected maize farmers respectively. While N2,050,180.35 ($4,881.38) and N1,095,245.61 ($2,607.73) were recorded as the Gross Margin (GM) of the not affected maize farmers and affected maize farmers respectively.

The Net Income (NI) of both the not affected farmers (N1,360,180.35 ($3,238.52)) and the affected farmers (N519,845.61 ($1,237.73)) were positive.

The Net Profit Margin Ratio (NPMR) were recorded as 36.33% and 26.66% for the not affected farmers and affected farmers respectively in the study area. The result reveals that maize farmers are making profit from their maize farming agribusiness. The buttresses the assertion of Liverpool-Tasie et al. (2017) that maize farming is profitable agribusiness in Nigeria and other African countries. Making final deduction that the not affected maize farmers were doing better profitable than the affected maize farmers will be ambiguous using the Net Income (NI) result. Therefore, to determine the efficient and competitiveness of an organization in perfect market, there is need to measure the output of the working capital and quantify the operational efficiency of such organization. Hence, the use of Net Profit Margin Ratio (NPMR) which according to Tulsian, (2014) reflects the true picture of an organization profitability showing the returns on investment of the organization in a competitive market economy over a period.

Table 2. Average Estimated Costs and Returns of Maize Production Per Annum Per Farm Values

	Not Affected				Affected				
Item of Cost	**Quantity**	**Unit Cost ₦ ($)**	**Total Revenue ₦ ($)**		**Quantity**	**Unit Cost ₦ ($)**	**Total Revenue ₦ ($)**		**Difference ₦ ($)**
A. Revenue Quantity of maize sold. Per 50kg bag	288 bags of 50kg	13,000/ 50kg bag (30.95)	**3,744,000 (8,914.29)**		150 bags of 50kg	13,000/ 50kg bag (30.95)	**1,950,000 (4,642.86)**		1794000** (4271.43)
Item of Cost	**Quantity**	**Unit Cost** ₦ ($)	**Total Cost** ₦ ($)	**% of TC**	**Quantity**	**Unit Cost** ₦ ($)	**Total Cost** ₦ ($)	**% of TC**	**Difference**
B. Variable Cost	**Not Affected**				**Affected**				
Planting Materials	4.8ha	9,739.84 (23.19)	46,751.25 (111.31)	0.20	2.5ha	9,739.84 (23.19)	24,349.6 (57.98)	1.70	22,401.65* (53.33)
Land preparation	4.8ha	90,723.63 (216.01)	435,473.40 (1,036.84)	18.27	2.5ha	90,723.63 (216.01)	226,809.08 (540.02)	15.86	208,664.32** (496.82)
Weeding	4.8ha	21,315.47 (50.75)	102,314.25 (243.61)	4.29	2.5ha	21,315.47 (50.75)	53,288.68 (126.88)	3.73	49025.57** (116.73)
Herbicide Application	4.8 ha	5,165.81 (12.30)	77,487.15 (184.49)	3.25	2.5 ha	5,165.81 (12.30)	12,914.53 (30.75)	0.90	64572.62 (153.74)
Harvesting	4.8ha	49,594 (118.08)	238,051.20 (566.79)	9.99	2.5ha	49,594 (118.08)	123,985.00 (295.20)	8.67	114066.2 (271.59)
Bagging	288 bags	356.80 (0.85)	102,758.40 (244.66)	4.31	150 bags	356.80 (0.85)	53,520.00 (127.43)	3.74	(49,238.40) (117.23)
Transportation	288 bags	570.50 (1.36)	164,304.00 (391.2)	6.89	150 bags	570.50 (1.36)	85,575.00 (203.75)	5.98	78729.00 (187.45)
Storage	288 bags	528.75 (1.26)	152,280.00 (362.57)	6.39	150 bags	528.75 (1.26)	79,312.5 (188.84)	5.55	72,967.5 (173.73)
Tax and Levy (10% of the selling price)	288 bags	1,300 (3.10)	374,400 (891.43)	15.71	150	1,300 (3.10)	195,000 (464.29)	13.63	179,400 (427.14)
Total Variable Costs (TVC)			**1,693,819.65 (4,032.90)**	71.05			**854,754.39 (2,035.13)**	59.77	839,065.26** (1997.77)
Gross Margin (GM)			**2,050,180.35 (4,881.38)**				**1,095,245.61 (2,607.73)**		954934.74** (2,273.65)
C. Fixed cost									
Depreciation (Farm equipment)			690,000 (1,642.85)	28.95			575,400 (1,370)	40.23	114,600 (272.85)
Total Cost (TVC + Fixed Cost)			**2,383,819.65 (5,675.76)**				**1,430,154.39 (3,405.13)**		953,665.26* (2270.63)
Net Income NPMR (NI/TR) x 100			**1,360,180.35 (3,238.52) 36.33%**				**519,845.61 (1,237.73) 26.66%**		840,334.74 (2000.79) 9.67%**

*10%, **5%, and ***1% significance levels. Note: $1 = 420 Naira

Table 3. Full Information Maximum Likelihood Estimates of Endogenous Switching Regression (ESR) Model for Combating Aflatoxin Using Agrochemicals and Impact of Combating Aflatoxin on Maize Output

	Selection		Not Farmers		Affected Farmers	
	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
Constant	0.8148	0.8646	8.0041	2.5414	0.0052	0.6157
Gender	0.2974	0.9563	0.58164*	2.5021	0.2358	1.8864
Age	0.131	0.36682.	0.02751	8.7508	8.1194***	11.4490
Age^2	- 0.0354***	0.1572	0.0118	0.9039	0.0066	0.4061
Marital Status	-0.4821	1.1528	0.7297*	2.1746	0.4087	2.0698
Years of Education	-0.0406	1.6113	-0.0118	0.6419	0.0380***	3.9169
Household Size	-0.0904	2.2401	-0.1402***	3.9038	0.0197	1.004
Farming Experience	0.09432***	4.5850	0.0485	2.6069	-0.0183	1.3231
Access to Credit Loan	-0.1991	0.9301	0.5148**	2.5807	0.1035	0.9039
Association/Cooperative Membership	-0.0131	0.0393	0.5201*	2.2008	-0.1651	1.1790
Family Labor	0.21484	1.9388	0.2266***	3.5370	0.2253	3.8121
Hired Labor	-4.3361	0.0917	0.001	2.4235	0.09	1.4410
Maize seedlings	0.00262	0.6419	-0.0026	0.8908	-0.0052	1.1659
Fertilizer application	-0.1585**	3.0916	-0.1821	2.8999	0.0157	0.6943
Herbicide	0.0013	0.0524	0.0878	8.2792	0.0938***	6.1308
Farm Size	0.7061***	3.8907	1.2065	8.9080	-0.3603***	7.0478
Awareness	0.6354*	2.0436				
$ln\sigma_1$			-0.2135*	2.1484		
ρ_1			-7.2744***	5.2531		
$ln\sigma_2$					-0.8463***	6.5238
ρ_2					+7.2260***	5.4889
Log likelihood	-209.50					
Likelihood ratio of independence: $\chi2(1)$			39.2476***			

Source: Computed from Field Survey Data, 2019.
Note: *, ** and *** represent significance at 10%, 5% and 1% levels respectively.

The 9.67% difference in the not affected maize farmers and the affected maize farmers NPMR significant difference shows the effect of aflatoxin on the profitability of production in the study area. The result shows that those who are not using agrochemicals to combat the effect of aflatoxin are losing 9.67% of their profit to the contamination of their maize by aflatoxin.

3.3. Determinants of Maize Usage of Agrochemicals to Combat Aflatoxin in the Study Area

Table 3 presents the factors influencing the maize farmers' using agrochemicals to combat aflatoxin in the study area (Selection column). The results can be demonstrated as normal probit coefficients. As shown in the column (Table 3), age^2 and fertilizer application were negatively significant with not affected status. The implication of this scenario is that the two variables decrease the likelihood of maize farmer's using agrochemicals to combat the effect of aflatoxin in the study area. The age2 reveals that an advanced in age (i.e., above 60 years) maize farmers will not be willing to use agrochemicals to combat the effect of aflatoxin on maize production in the study area. Since such farmers are old, they will not have the strength and vigor to cultivate a large farm, hence, they will not see the need to spend much in buying agrochemicals to combat the effect of aflatoxin. In Sub-Sahara Africa (SSA), the older a farmer is, the less he/she is willing spend on the farm. This also buttress the findings of Wambua et al., (2021) among Coffee farmers in Kenya.

The implication of the negative relationship that existed between fertilizer and application of agrochemicals to combat aflatoxin among the maize farmers indicates that an increase in fertilizer application reduces the probability of farmers' using agrochemicals to combat aflatoxin. Most maize farmers believed that the application of fertilizer will increase their output, hence, farmers that use more fertilizer will not see the need for another agrochemicals to combat aflatoxin again to increase their output which is in line with the conclusion of Ali et al., (2018) between smallholder cocoa farmers in the Western Region of Ghana. Whereas the positive value of farm size and the significant relationship with the usage of agrochemicals implies that an increase in the farm size of the maize farmers increases the probability of using agrochemicals to combat the effect of aflatoxin in the study area. The findings of Tidgren, (2017) in United States of America (USA) shows that farmers with large farm size would like to protect his/her investment compare to farmers with small farm size.

Awareness of using agrochemicals to combat aflatoxin was positively significant with the using agrochemicals to combat aflatoxin. This is probably because information of what to do, when to do and how to do determines the action of farmers at any point in time. So, the need for the extension agents to be close to the farmers to furnish them with relevant information on farming. This supports the findings of Elias et al., (2015), that farmers who are frequently visited by the extension agents are more productivity than those who are not in most developing countries. Farm experience is positively significant with usage of agrochemicals to combat aflatoxin showing that the higher the farm experience, the more the likelihood of using agrochemicals to combat the effect of aflatoxin by maize farmers in the study area. So, farm experience enables the farmers to know what to do to enhance their output and increase their income from farming activities based on the knowledge gathered over the years Danso-Abbeam et al., (2018).

3.4. Effects of Household and Farm Characteristics of Maize Farmers on Maize Output

Table 3, column four (Not affected maize farmers) and six (Affected maize farmers) revealed the likelihood ratio tests for joint independence of the equations in Endogenous Switching Regression (ESR) model were dependent. The Table and columns show that for not affected, and affected farmers, the correlation coefficients ρ_1 and ρ_2 were individually statistically significant, signifying that there was selection bias due to unobservable variables. So, ESR model is suitable for the analysis as used by Haregewoin, (2021) in his study on irrigation impact on crop output in Tigray, Ethiopia. However, ρ_1 was negative while ρ_2 was positive, showing that the output of the not affected maize farmers is more than a random farmer from the sample, while the output of the affected maize farmers is lower than a random farmer from the sample. The outcome equation in Table 3, column four (4) for not affected farmers, and column six (6) for affected farmers shows how the household and farm-level characteristics affects maize farmers' output.

From the Table and columns, gender, marital status, access to credit facilities, membership of an association or cooperative, and family labor were positive and significantly affects maize output among the not affected farmers (column four). This shows that an increase in these variables will likely increase the maize farmer's output among the not affected farmers. A male maize farmer would bring about an increase in maize farmer's output among the not affected farmers. This tally with the results of Hijbeek et al. (2018) in their study on "What drives farmers to increase soil organic matter? Insights from the Netherlands Soil Use and Management" that the more the male farmers, the higher the farmers joint output because of their strength and vigor to do farm work.

The marital status was positive and significant different from zero with coefficient that is positive among the not affected farmers, this indicates that there is likelihood for the output of the not affected to increase because of being married status. Being married will likely enhance large family size that can be used for family labor compared to those who are not married. This assertion buttresses the findings of Kwapong et al. (2021) in their study on "Determinants of scale of farm operation in the eastern region of Ghana" that the higher the number of married farmers, the more likely the increase in farmer's output. Access to credit facilities, was positive and significant statistically among the not affected farmers. This result shows that access to credit facilities will lead to increase in not affected maize farmer's output. This confirms the assertion of Awunyor-vitor, (2018) which stated that there is high positive relationship between access to credit facilities and farmer's output. Belonging to an association or cooperative was positive and significant among the not affected farmers. This implies that as farmer belongs to an association or cooperative society there is high probability that his/her maize farm output will increase. Belonging to an association or cooperative society boosts farmers access to credit facilities, bulk purchase of inputs through association negotiating on behalf of their members and access to market information that will enhance sales of output at competitive price in the market domain.

Table 4. Impact of Land Renting

Variable	Not Affected Farmers kg/ha	Affected Farmers kg/ha	ATE T-test	Net Change (%)
Output	662	571	8. 00***	15.94

Source: Computed from Field Survey Data, 2019
Note: *** represent significance at 1% levels

Family labor was positive and statistically significant among the not affected farmers, showing that the more family members of the not affected maize farmers that are involved in maize farming, the higher the maize output. According to Colnago and Dogliotti, (2020), the cost of production in the long run will reduced because of the increase in the number of family members that involved in maize production. Household size and fertilizer application negatively and significantly affects maize output among the not affected farmers. This shows that there is likelihood of reduction in the maize output among the not affected maize farmers because of increase in the family size and usage of fertilizer. There is possibility of increase in the family expenditure, consumption, and couple with the cost of buying agrochemicals to combat aflatoxin will negatively affects the farmers productivity. This tally with the findings of Ahmed et al. (2017) in their study.

Age, years of education, and herbicide positively and significantly affects maize output among the affected maize farmers. The statistically positive and significant value of age among the affected farmers shows that maize output will likely increase as farmers age of the affected maize farmers increases, buttressing the results of Danso-Abbeam et al. (2018) in their study, that among the factors that positively affects farmer's output is their age. The year of formal education of the affected maize farmers had positive value in the equation, this shows that the more educated the affected maize farmers are, the higher their maize output. This buttresses the finding of Padhy and Jena, (2015) in their study. The estimate for the quantity of herbicide used was positive and statistically significant for affected farmers, indicating the positive impact of the quantity of herbicide on farmer's output. As the farmers use more herbicide to control weed on the crop production for affected farmers, it will lead to more output of maize. This supports the assertion of Gashaw et al. (2017) in their research.

The negative and significant value of farm size for the affected maize farmers in the equation shows that as the farm size increases, there is likelihood of reduction in the maize output. Large farm size give room for the appropriation of the benefits of large-scale production, such as bulk buying of inputs, application of technology and innovations (Rada and Fuglie, 2019).

3.5. Estimating the Effects of Using Agrochemicals to Combat Aflatoxin On Maize Farmers' Output

Maize farmer's output could be influenced by the household and farm characteristics; hence, this was addressed by estimating an ESR model, which gives room for the construction of a valid counterfactual hypothetical case of not affected by aflatoxin maize farmers and affected maize farmers. The effect of aflatoxin on maize output is presented in Table 4 by the estimation of Average Treatments Effects (ATE) on the treated in the ESR model specifications. To assess the effect of aflatoxin on maize output, the ATE on the anticipated outcome was calculated. It is imperative to note that ATE calculation consider other hidden factors such as selection bias ensuing from possible variations between not affected and the affected maize farmers as opined by Hughes et al. (2019). The results showed that aflatoxin significantly reduced the output of maize farmers in the study area. To be specific, the expected output of not affected maize farmers was 662kg/hectare compared with 571kg/hectare from affected farmers. The difference represents 15.94% reduction in the output of the affected maize farmers. This confirms the findings of Yazd et al. (2019) that access to information and knowledge positively influence farmer's output.

4. Conclusion

The study assessed the effect of aflatoxin on the profitability and output of maize in southwest, Nigeria. The result showed that aflatoxin reduced the maize farmer's profitability and maize output in the study area. Government at various levels, national and international donors should sensitize the maize farmers and other arable crops farmers on the need to combat the effect of aflatoxin on their farm output using agrochemicals. The study added empirically to the existing literature on the effect of aflatoxin on maize farmers' profitability and output in Nigeria and other African countries.

The following policy can be deduced, firstly, maize farmers who were not affected by aflatoxin had higher returns on their investment than those who were affected. Therefore, maize farmers should be sensitized to the need to combat the effect of aflatoxin by using appropriate agrochemicals. Secondly, youth should be encouraged through sensitization and workshops on the need to use agrochemicals to combat the effect of aflatoxin, as shown in the study, advanced in age maize farmers may not be willing to use agrochemicals to combat aflatoxin. Extension agents should be frequent with them and teach them what quantity to use, when and how to use the agrochemicals. Therefore, there is a need for governments, national, and international donors who are willing to support the youths in agribusiness to combat aflatoxin using agrochemicals.

Third, extension agents should visit the maize farmers to enlighten them on the expected quantity of fertilizer that will increase their yield. This is necessary since it is an important variable that influenced the output of the maize farmers not affected. So, if its usage is properly monitored by the extension agents, maize farmers' output in Nigeria and Sub-Sahara Africa (SSA) will surely be enhanced generally using the appropriate type and quantity of fertilizer.

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List of Abbreviations: ATE, Average Treatment Effect; ESR, Endogenous Switching Regression; IITA, International Institute for Tropical Agriculture; NPMR, Net Profit Margin Ratio; SSA, Sub-Sahara Africa.

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